Wind-Turbulence-Wave Interactions

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LONG-TERM GOALS

The long-terms goals of the research are to understand and parameterize the physics of air –sea interaction, and in particular wind-wave interaction. The effort is primarily experimental, based on measurements over the sea under a variety of wind-wave conditions. Applications are to EO propagation and scintillation over the ocean.

OBJECTIVES

The objective is to develop similarity parameterizations of air-sea interaction and the MABL. Underlying this is the improvement of the basic understanding of wind-wave physics.

APPROACH

The approach is in-depth analysis of the wind, turbulence and wave data obtained in the Marine Boundary Layers ARI experiment from R/P *FLIP*. Approximately 7 GB of data were obtained. Spectral, statistical and other analyses are applied to the data to determine the physics of wind-wave interaction and parameterizations of air-sea interaction.

WORK COMPLETED

Phase averaging techniques were developed to extract the wave-coherent signals submerged in the larger turbulent wind signals. Hilbert transform and zero-crossing methods were applied to the MBL data set. Wind profiles and wind stress variations were determined.

RESULTS

The wind profile generally is similar to that in the surface layer over land – i.e., a semi-logarithmetic variation of speed with height – except at low wind speeds with a large swell sea running. In these conditions, the profile exhibits less shear near the surface and stress co-spectra indicate a transfer of momentum *from* the waves to the wind at the peak swell frequency.

The basic tenet of surface-layer turbulence theory is that the stress is constant with height, to within about 10%. Stress divergence is neglected. Scaling theory suggests that the height of the surface should increase with the magnitude of the stress. However, the stress divergence results from the MBL experiment show the opposite. At low winds (low wind stress), divergence is negligible. It increases

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with wind speed, and at 15 m/sec there is a 40% decrease of the stress between the surface and 18m height. This is presumably due to a non-linear response from the generation and maintenance of wind waves. The stress profile for 4 ranges of stress are shown in Figure 1.

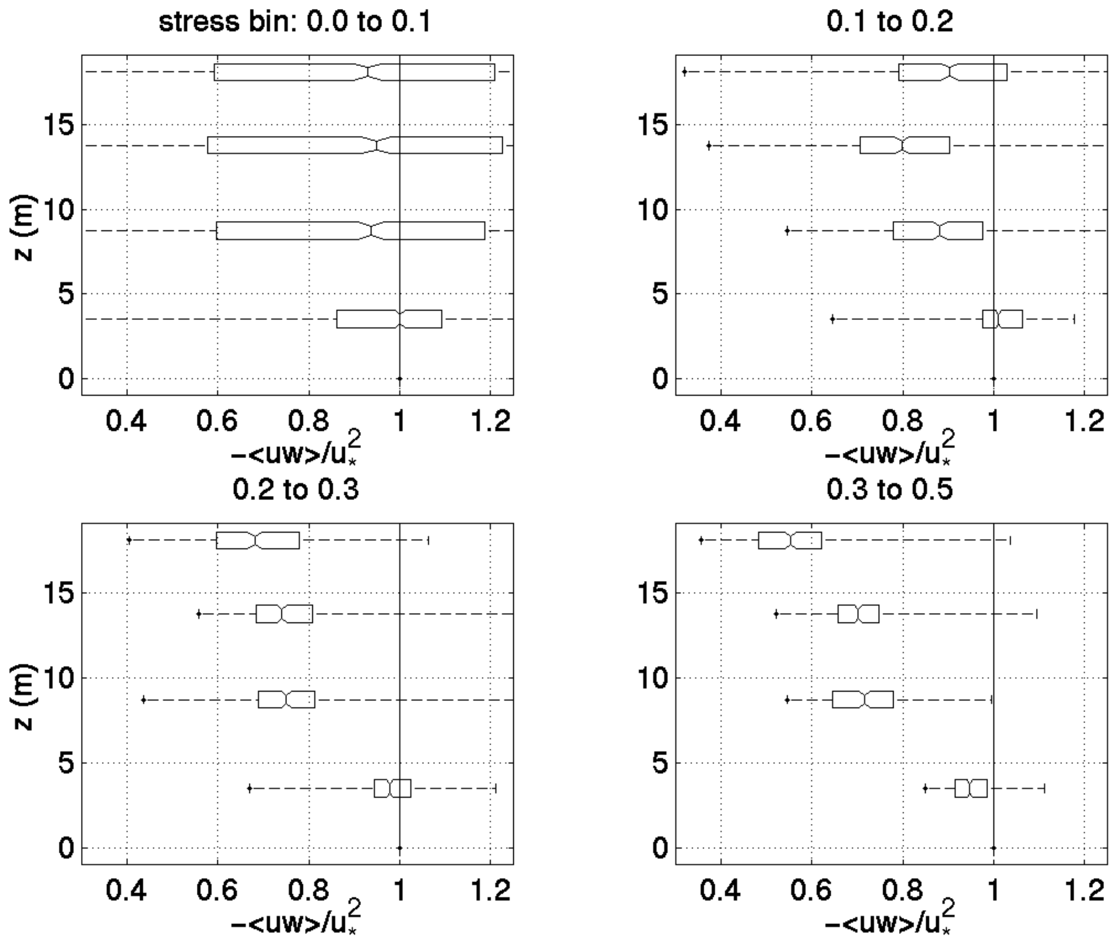

Figure 1: Stress profiles for 4 ranges of stress (u*, m/sec) from the MBL FLIP experiment. Stress divergence increases as wind speed (stress) increases. Results are shown for each level as "box plots," which show the mean and extent of scatter.

IMPACT/APPLICATIONS

The impacts of the research will be in the improvement of the basic understanding of air-sea interaction processes in particular the physics of wind-wave coupling. The research will lead to better parameterizations of air-sea interaction, such as the wind stress, through incorporation of wave effects.

The result of significant stress divergence in the lower 20 m above the waves in high winds suggests that the traditional application of a drag coefficient formulation, which assumes a constant stress layer, will have to be changed. Past data of wind speed and stress at the canonical height of 10 m would have under-estimated the surface wind stress. The results should have impact on wave forecasting models and large-scale weather models.

TRANSITIONS

The Navy Space and Naval Warfare Systems Command, SPAWAR, contacted us about measurements of wave effects on radar and optical propagation in the surface layer over the ocean. Propagation measurements have implied that there are possible significant effects of surface waves on ducting for moderate to high wind speeds. Several meetings were held and an integrated experiment was planned, Rough Evaporation Duct, to be centered on the Research Platform *FLIP* in fall 2001.

RELATED PROJECTS

Temperature and humidity data from the MBL FLIP project were analyzed with the phase-averaging Hilbert transform technique and revealed fluctuations coherent with the waves. Therefore there are fluctuations in the refractive index of moist air at wave frequencies, which will affect EO propagation over the sea.

PUBLICATIONS

Journal Papers:

Fuehrer, P. L. and C. A. Friehe, ``A Physically-Based Turbulent Velocity Time Series Decomposition," Boundary-Layer Meteorology, **90**, 241-295 (1999).

Miller, S. D., J. Edson, T. Hristov, C. A. Friehe and S. Wetzel, "Wind and Turbulence Profiles over Open Ocean Waves," in 'Wind-Over-Waves Couplings: Perspectives and Prospects,' Institute of Mathematics and Its Applications Conference Series, New Series Number 69, S. G. Sajjadi et al., eds., Oxford University Press, 91-98 (1999).

Hristov, T., Miller, S. D., J. Edson, C. A. Friehe and S. Wetzel, "Structure of the Atmospheric Surface Layer over Open Ocean Waves: Representation in Terms of Phase Averages," in 'Wind-Over-Waves Couplings: Perspectives and Prospects,' Institute of Mathematics and Its Applications Conference Series, New Series Number 69, S. G. Sajjadi et al., eds., Oxford University Press, 99-106 (1999).

Presentations:

Hristov, T., C. A. Friehe, S. Miller and J. B. Edson, ``Identification and Analysis of Wind-Wave Interactions in Field Experiment Data," Thirteenth Symposium on Boundary Layers and Turbulence, American Meteorological Society, pp. 233-236 (1999).

Miller, S. D., C. A. Friehe, T. Hristov, and J. B. Edson, ``The Wave-Induced Wind Field Above Deep Ocean Waves," Thirteenth Symposium on Boundary Layers and Turbulence, American Meteorological Society, pp. 237-240 (1999).

Hristov, T. and C. A. Friehe, ``Linear Time-Invariant Compensation of Cup Anemometer inertia," Thirteenth Symposium on Boundary Layers and Turbulence, American Meteorological Society, pp. 399-402 (1999).